# PART I

## Background to the Competition

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Of the 1.6 million workers in the Construction Industry, about 1 million are employed in trades likely to involve a considerable amount of outdoor work. They, their employers, and indeed the whole nation will suffer financial loss from the slowing down or abandonment of work during bad weather, unless certain precautions are taken to enable them to continue working. Among the most important - and a statutory requirement - is the provision of adequate protective clothing.

Research carried out by the Directorate General of Research and Development of the Ministry of Public Building and Works has shown that the clothing traditionally used by outdoor workers on building and civil engineering sites does not provide adequate protection against bad weather.

This lack of adequate protective clothing accounts for a great deal of the arthritis, rheumatism and bronchial complaints in the construction industry, the incidence of which is higher than the average for Industry in general. It is also a factor in the steady drain from the industry of men over the age of 35 who seek better working conditions elsewhere. Furthermore, with overheads and wages rising rapidly, it costs the industry a great deal of money when men are unable to work owing to bad weather.

The development of protective clothing suitable for use in the construction industry would have economic advantages, not just for the industry, but for the country as a whole. It would, by improving working conditions, enhance the status of the industry and so ensure its future development and prosperity.

In addition, there are large numbers of workers employed on outdoor work in other industries - agriculture, transport, the public utilities etc. - for whom similar protection against bad weather is needed. There is also a considerable export potential for good protective clothing since many European countries have similar climatic problems to our own and need the same basic protective clothing.

Over the past few years much development work on protective clothing has been done by the Directorate General of Research and Development, with the co-operation of a number of firms in the construction industry.

The information gained from this work made it possible to determine the basic requirements for both the design and the material of the garments. By 1967, the work of the Ministry in this field had reached the point where it was felt that much would be gained from the participation of the clothing industry; consequently the Minister decided to promote a competition for the design of a range of protective clothing for outdoor workers on building and civil engineering sites.

The object of the competition was to stimulate interest in the design of protective clothing which meets the needs of the user on the construction site more fully than that which is currently available. The competition took the form of a design and assessment exercise, competitors being invited to submit samples of protective clothing - made to the general performance specification in Part II of this Report - for testing and assessment by a Panel.

The Panel was appointed by the Minister to advise him on the conduct of the competition, to arrange testing and assessment, to adjudicate on all the entries submitted and to make awards. The members of the Panel were:

Chairman

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| Mr. E. O. Baillie | (Joint Managing Director, Gilbert-Ash Limited) |
| Mr. R. G. Calverley | (Deputy Chairman, Mayfield Corporation) |
| Mr. S. Hind | (Labour Officer, Ministry of Public Building and Works) |
| Mr. J. H. Mills, C. B. E. | (President, National Federation of Building Trade Operatives) |
| Mr. J. R. Smith | (Winter Building Adviser, Ministry of Public Building and Works) |
| Mr. J. Swinburn | (General Foreman, M. & F. O. Foster & Co. Ltd. ) |

Secretary

| | |
|---|---|
| Mr. W. J. Marsh | (Ministry of Public Building and Works) |

PART II

## An Outline Performance Specification for Protective Clothing for Workers on Construction Sites

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The following performance specification was issued to all competitors:

### Preamble

This specification is intended to be a guide to the requirements of the user of protective clothing on construction sites, but no attempt has been made to influence the type of material or the design of the garment. The specification is only concerned with the efficiency and safety of protective clothing for use on construction sites, and as such gives an outline of the minimum requirements for this purpose. Garments designed to meet this specification must, however, not only provide suitable protection from the elements but also be acceptable in appearance to the average wearer.

### Function

This clothing is intended to provide protection in all weather conditions throughout the year to all outdoor trades and labourers within the building and civil engineering industry. It is also intended to provide where necessary suitable protection for supervisory, technical and engineering staff on construction sites.

### Garments required

No specific design of clothing is required. It is necessary however that the clothing produced protect the wearer from neck to ankles. The inclusion of weather protection for the feet and hands in the design is acceptable. The clothing produced may include ancillary garments for different weather conditions. Headwear may be included in the design, but the importance of safety and clear hearing and vision must be borne in mind.

### Safety

All garments must be produced with the problem of safety on construction sites in mind. This will necessitate design of garments with no loose skirts, cuffs, belts or projecting fastenings. Pockets must be inset or protected by flaps. Colour, which is vital from a safety aspect, should be considered by the designer.

### Ease of movement

Both as a safety and industrial requirement the garments produced must not unduly hinder or restrict movement. The most important aspect of this is the freedom of the wearer to lift his arms above his head. Such an action shall be easy and without restraint imposed by the clothing. Should any part of the garment be subject to undue tensile stress as a result of the wearer of a properly sized suit crouching, climbing or reaching up, the clothing will not meet this specification.

### Weight

The dry weight of the clothing should not exceed the following:

| | |
|---|---|
| Complete suit of clothing providing protection for the body, legs and arms from the neck to the ankles and wrists | 4 lb. |
| If protection for the feet (size 9) is included with the suit | plus 4 lb. |
| If protection for the hands is included with the suit | plus 8 oz. |
| If protection for the head is included with the suit: | |
| If weather protection only | plus 4 oz. |
| If weather and safety protection combined | plus 8 oz. |

### Warmth

The warmth provided by the garments shall be sufficient for men doing manual work between temperatures of $0^{\circ}$F and $60^{\circ}$F. This can be achieved by adding or removing garments or linings etc. This is an essential user requirement and the designer must make provision for, or give consideration to, this varying requirement.

### Water resistance and permeability

The material of which outer garments are fabricated must be water-resistant and must allow the passage of sufficient air for user comfort either by means of the permeability of the material or by artificial ventilation or a combination of both.

**Flame resistance**

The material of which all garments are made must provide an adequate resistance to flame which will be evaluated in respect of the duration of flaming and afterglow and the length of material charring or melting.

**Durability**

The materials used for outer garments must provide a reasonable standard of resistance to abrasion, provide a tear strength of at least 6 lb across warp and 5 lb across weft where appropriate, and possess adequate strength for reasonable wear and tear performance.

Colour fastness will also be a determining factor both in respect of colour loss and colour staining, as will resistance to weathering.

**Oil and chemical resistance**

The material of which outer garments are made shall be resistant to the effects of diesel fuels, lubricating oil and alkaline solutions with the exception of caustic soda solutions.

**Resistance to cracking**

The materials of which the garments are made must provide adequate and suitable resistance to cracking which will be evaluated in respect of flex cracking, flex cracking after ageing and cold crack.

**Manufacture**

**Fastenings.** All fastenings shall be of such a design that they cannot catch on objects such as protruding bars and tubes. It is desirable that they should be capable of being done up and undone with one hand, and they must be protected from or unaffected by icing up, cement and similar building materials, and general wear and abrasion. Fastenings to the front of outer garments must be capable of withstanding an imposed load across the line of the fastenings of 100 lb and a shock load of 15 lb dropped 5 feet without failure of the fastening. All fastenings to the front of garments, cuffs, collars, trousers, etc., must withstand a use cycle of 5,000 without failure.

Seams. An important factor in the assessment of garments will be the degree to which the seams, whether welded or sewn, are waterproof. The seam strength should be not less than three-quarters of the tensile strength of the material and resistance to slippage should be not less than three-eighths of the tensile strength. Threads used for seams must be suitable for the material used.

## External pockets

These should not present a safety hazard in any manner. Consideration will be given to this factor and to the degree to which the pockets are waterproof.

## Size

Garments must be made in B. S. size 40.

# PART III

## The Entries to the Competition

The Competition was launched in May 1967, and was open to all those already in, or associated with, the clothing trade, and any others interested in entering this market. The Competition received wide coverage in the Press and copies of the Conditions of the Competition were obtainable either direct from the Ministry or from the clothing trade associations. By the end of November 1967, twenty-two manufacturers had submitted thirty-seven entries for testing and assessment. The only specification requirements provided were the details set out in Part II, which endeavoured to give the manufacturer a guide to the requirements of the user of protective clothing on building sites.

Each entry consisted of six sets of garments, plus 2 sq yd of the relevant fabrics for laboratory tests. Of the six sets of garments comprising each entry, four were sent to different construction sites for site testing, one was sent to the testing laboratory for examination and destructive tests and the remaining suit was retained by the Ministry of Public Building and Works as a sample or datum with which to compare worn or damaged suits. Site testing began in December 1967 and was completed at the end of the first week of April 1968. Laboratory testing began in November 1967 and was completed at the end of March 1968.

The following sets of garments were entered for the Competition and tested:

| Identification Number | Style | Material |
|---|---|---|
| 12 | 3-piece suit | |
| | Smock | P. V. C. coated nylon |
| | Trousers | P. V. C. coated nylon |
| | Inner warmth smock | 10-oz cotton sailcloth; quilted lining, cellulose acetate and viscose with kapok wadding |

| Identification Number | Style | Material |
|---|---|---|
| 13 | 3-piece suit | |
| | Jacket with hood | Polyurethane coated nylon. |
| | Trousers | Polyurethane coated nylon. |
| | Inner warmth lining | Foam backed nylon. |
| 14 | 2-piece suit | |
| | Jacket | Both in 'Multithene'. |
| | Trousers | Yoke - polyurethane coated nylon |
| 15 | 2-piece suit | |
| | Jacket | Outer: Polyurethane coated 3. 7-oz nylon silicone finish.<br>Lining: Polyurethane coated 1. 7-oz nylon. |
| | Trousers | Polyurethane coated 3. 7-oz nylon silicone finish. |
| 16 | 3-piece suit | |
| | Jacket | Nylon reinforced P. V. C. |
| | Donkey Jacket | 31/33 oz siliconised Melton. |
| | Trousers | Nylon reinforced P. V. C. |
| 17 | 3-piece suit | |
| | Jacket, blouse type | P. V. C. coated nylon. Yoke and cuffs P. V. C. -coated viscose. |
| | Trousers | P. V. C. coated nylon. |
| | Inner warmth | Melton. |
| 18 | 4-piece suit | |
| | Jacket | Polyurethane coated cotton. |
| | Under jacket | Polyurethane coated cotton. |
| | Winter trousers | Polyurethane coated cotton. |
| | Summer trousers | Denim top 6 in. with denim front piecing. Polyurethane coated nylon. |
| 21 | 3-piece suit | |
| | Jacket | Nylon reinforced P. V. C. |
| | Trousers | Nylon reinforced P. V. C. |
| | Detachable lining | Lightweight Melton type. |

| Identification Number | Style | Material |
|---|---|---|
| 23 | 2-piece suit | |
| | Jacket with hood | Polyurethane proofed nylon. |
| | Trousers | Polyurethane proofed nylon. |
| 24 | 2-piece suit | |
| | Jacket | Polyurethane coated nylon.<br>Lining - nylon. |
| | Trousers | Polyurethane coated nylon.<br>Lining - (half) - nylon. |
| 25 | 2-piece suit | |
| | Jacket | P. V. C. coated nylon. |
| | Trousers | P. V. C. coated nylon. |
| 26 | 2-piece suit | |
| | Jacket | P. V. C. coated nylon. |
| | Trousers | P. V. C. coated nylon. |
| 27 | 3-piece suit | |
| | Jacket | P. V. C. coated nylon. |
| | Trousers | P. V. C. coated nylon. |
| | Detachable inner warmth garment | Nylon fabrics, acrylic wadding |
| 28 | 2-piece suit | |
| | Jacket | Polynosic reinforced P. V. C. |
| | Trousers | Polynosic reinforced P. V. C. |
| 31 | 1-piece boiler-suit type garment | Main fabric - nylon.<br>Lining fabric - nylon.<br>Wadding - polyester. |
| 32 | 2-piece suit | |
| | Smock with detachable hood<br>Trousers | Both in 'Gannex' type, nylon/synthetic/rubber/warp knit nylon laminate. |

| Identification Number | Style | Material |
|---|---|---|
| 35 | 3-piece suit | |
| | Jacket | Chlorosulphonated polyethylene coated nylon, with silicone finish to face. |
| | Trousers | As jacket. |
| | Inner warmth garment | Viscose nap/rubber/cotton laminate, foam interlining and lining of cotton ground/viscose pile. |
| 36 | Jacket with inner warmth | Silicone proofed cotton twill/polyurethane foam/cotton interlock laminate. |
| | Inner warmth | 'Kaycel' (cellulosic bonded fibre with nylon reinforcing yarns) |
| 38 | 2-piece boiler suit type | Polyurethane proofed cotton drill/polyurethane foam/knitted cotton scrim laminate. |
| 39 | 2-piece suit | |
| | Jacket with fixed hood | Polyurethane coated nylon viscose satin lining, cotton backed gauze wadding |
| | Trousers | Polyurethane coated nylon. |
| 40 | 2-piece suit | |
| | Jacket with attachable hood | Melton/foam/stockinette laminate, hood lined cotton |
| | Trousers | Melton/foam/stockinette laminate. |
| 41 | 3-piece suit | |
| | Jacket with attached hood | Polyurethane coated nylon with silicone finish |
| | Trousers | Polyurethane coated nylon with silicone finish |
| | Inner warmth | Brushed nylon/foam/stockinette laminate. |
| 43 | 2-piece suit | |
| | Jacket | Proofed nylon, lining nylon with polyester wadding. |
| | Trousers | Proofed nylon. |

| Identification Number | Style | Material |
|---|---|---|
| 44 | 2-piece suit | |
| | Jacket | Polyurethane coated nylon: lining - foam-backed nylon |
| | Trousers | Polyurethane coated nylon |
| 47 | 2-piece suit | |
| | Jacket and attached hood | Polynosic reinforced P. V. C. |
| | Trousers | Polynosic reinforced P. V. C. |
| 48 | 3-piece suit | |
| | Jacket with detachable hood | P. V. C. coated nylon |
| | Trousers | P. V. C. coated nylon |
| | Detachable lining | P. V. C. coated knitted nylon, foam-backed |
| 49 | 3-piece suit | |
| | Jacket with detachable hood | Polyurethane coated nylon |
| | Trousers | Polyurethane coated nylon |
| | Detachable lining | Foam-backed P. V. C. coated knitted nylon |
| 51 | 2-piece suit | |
| | Jacket with attached hood | Nylon/rubber/50 : 50 wool : cotton laminate |
| | Trousers | Nylon/rubber/50 : 50 wool : cotton laminate |
| 52 | 2-piece suit | |
| | Jacket | Nylon reinforced P. V. C. |
| | Trousers | Nylon reinforced P. V. C. |
| 53 | 2-piece suit | |
| | Jacket with sou'wester | Nylon reinforced P. V. C. |
| | Trousers | Nylon reinforced P. V. C. |

| Identification Number | Style | Material |
|---|---|---|
| 54 | 2-piece suit | |
| | Jacket with attached hood | P. V. C. -coated nylon |
| | Trousers | P. V. C. -coated nylon |
| 55 | 2-piece suit | |
| | Jacket | Polynosic reinforced P. V. C. |
| | Trousers | Polynosic reinforced P. V. C. |
| 56 | 2-piece suit | |
| | Smock | P. V. C. -coated nylon |
| | Trousers | P. V. C. -coated nylon |
| 57 | 1-piece boiler suit type | Polyurethane-coated nylon |
| 58 | 2-piece suit | |
| | Jacket | P. V. C. -coated nylon |
| | Trousers | P. V. C. -coated nylon |
| 59 | 3-piece suit | |
| | Jacket | Polyurethane-coated silicone proofed nylon |
| | Trousers | Polyurethane-coated silicone proofed nylon |
| | Inner warmth | Rayon with kapok filling |
| 60 | 1-piece suit with inner warmth | Polyurethane-coated silicone proofed nylon |
| | Inner warmth | Rayon with kapok filling |

## PART IV

## Method of Testing and Assessment Used

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### Site testing

The Directorate General of Research and Development had acquired a considerable knowledge of the specialised techniques needed to conduct serviceability testing in the Construction Industry, from the on-site testing of its own prototype protective clothing designs during the winters of 1964/65 and 1966/67. These two periods of site testing made it possible to identify the problems involved. These are:

(i) The variety of tasks undertaken by the different trades and by men in the same trade on a construction site.

(ii) The variety of weather conditions encountered on different sites at the same time of the year in differing geographical locations.

(iii) The difficulty of controlling the use of the sample protective clothing with the amount of supervision which can be provided for this purpose on construction sites.

(iv) The danger of losing the sample garments before the trials have been completed, particularly when sample garments are worn by transitory labour.

(v) Organising the feedback of unprejudiced information from the wearer to the research group.

(vi) Arranging for assessment of the quality of the information provided.

### Selection of sites

In selecting the sites where four of the six suits provided by each competitor were to be tested, two factors had to be taken into account:

(1) the need to test the suits under the differing weather conditions likely to be met throughout the country;

(2) the need for adequate supervision and organisational convenience, which meant that the optimum number of suits which could be allocated to any one site was between 10 and 20.

These factors led to the selection of sites at the following ten places:

Helensburgh, Dunbartonshire
Sunderland, Co. Durham
West Bridport, Nottinghamshire
Stevenage, Hertfordshire
Waltham Cross, Hertfordshire
Euston, London
Southall, Middlesex
Poplar, London
Dulwich, London
Aldershot, Hampshire

### Selection of wearers

The selection of the operatives who would wear the protective suits during the test period was influenced by two considerations. First, the decision to conduct the testing during the entire winter period meant it was necessary to select men from those trades which would be continuously employed on site, as distinct from highly specialised trades which would only be engaged on any one site for a short period. Second, to ensure that the suits would be submitted to a reasonable amount of abrasion, it was necessary to select men from trades engaged in arduous manual work.

The wearers were selected from these trades:

Formwork carpenter
Bricklayer
Industrialised building system erector
General labourer.

Contractors were asked to issue the clothing to reliable employees in these trades.

### Control of site testing

To control the use and ensure the retention of the garments, the names of the wearers were obtained from the contractor's representative responsible for issuing the clothing, and the serviceability testing was conducted on the basis of personal contact with the wearer. In addition, the interviewer would ask to see the garment or at least to be told of its location during every site visit, whether the garment was actually being worn at the time or not. This personal approach and the interest in the whereabouts of the garment created an atmosphere of interest and personal concern for the security of the garment in the wearer.

The feedback of information from serviceability testing of this type is of great importance, and to ensure rapid feedback to the Directorate General of Research and Development information was gathered directly by their interviewers from the wearers on the different sites, rather than through intermediaries or supervisory employees of the contractor. The method adopted was to visit the site and interview the wearer at intervals of approximately two weeks. There were two types of interview which alternated. The first consisted of a report of the wearer's opinions, this information being noted down on a simple box-type questionnaire which could be completed either by the interviewer or by the wearer. This enabled the wearer's opinion of the way the garment had stood up to the weather conditions during the preceding two weeks to be obtained. The second type of interview was more detailed and in addition to the completion of the simple questionnaire mentioned above required the filling in of a report form by the interviewer. In this he assessed the condition of the garment, wear patterns if any, the type of damage, the validity of the wearer's opinions and the quality of the information given on the simple questionnaire. This second interview and report required a detailed examination of the clothing. The information thus obtained was returned to the Directorate General of Research and Development where a record of the interview was made on a master control sheet. At the same time a simple but comprehensive monthly weather chart was maintained by the site agent to give a complete background to the weather conditions which had affected the wearer's opinions of the garment.

The quality of the information obtained was assessed by relating it to the amount of wear that the garment had received, the type of work which the wearer had been engaged upon and the interest, intelligence and co-operation shown by the wearer. It was recognised that a successful garment must appeal to the potential wearer and considerable importance was placed during the interviews in assessing the acceptability of the garment to the wearer. This could frequently be gauged by the amount of wear to which the garment had been subjected. In some cases, garments had been worn every working day during the entire test period and for some more popular garments it was claimed by construction site humourists that the garments had been worn socially as well. On the other hand certain garments appeared to be unacceptable to the normal construction worker and received very little wear. This was accepted as a reasonable guide to the popularity of the particular garment and was considered a relevant factor in assessing its effectiveness.

## Laboratory testing

In order to obtain the same objectivity in the laboratory testing it was decided to seek the services of an independent testing laboratory known to the clothing industry. A contract for testing to a predetermined programme was arranged with such a laboratory and the test methods to establish the performance of the garment and the materials were agreed with its Technical Director. The programme provided for a detailed examination of the suit, its dimensions, the weight of the complete suit and its components, together with details of seam strength, strength of zips and the water resistance of seams. Tests were carried out on the fabric to establish tensile strength, tongue tear strength, water resistance, air permeability, flammability, abrasion resistance, heat ageing, resistance to flex cracking, cold crack temperature, shrinkage, colour fastness, the effect of solvents and the bond strength. Where possible all tests were carried out to the appropriate British Standard.

Periodic visits were made to the laboratory so that any unusual test results could be related to the field performance of a particular material or garment. In addition, occasional visits were made by the Director of the laboratory to sites to gather information that would enable the laboratory testing to be related to actual field conditions. An interim report was provided by the laboratory followed by a final detailed report on the performance of each entry during the tests described above.

## PART V

## Assessment of Entries

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### Wearer acceptability

If the design of the protective clothing causes the wearer to feel self-conscious or otherwise ill at ease, the clothing will not readily be worn. For this reason the acceptability of the clothing to the wearer was considered to be of paramount importance. Entry numbers 13, 14, 15, 18, 23, 35, 36, 43, 44 and 59 were the most popular designs and were worn consistently throughout the period of site testing. The designs of some of the other entries did not seem to take account of wearer acceptability and consequently it was difficult to find people who were willing to wear suits from those entries for the period of the site testing.

### Function

Many of the entries could be considered only as waterproof and not as protective clothing, since they did not offer protection in **all** weather conditions and could not, therefore, be said to have met the requirements of the outline performance specification.

### Garments required

Entry number 36 consisted simply of a jacket which although a very popular and efficient garment provided incomplete protection. In a number of cases the jacket of a 2-piece suit was so short that, if the wearer stretched or bent over, a gap appeared between the jacket and the trousers.

### Safety

A number of the garments entered showed a lack of consideration of the detailed problems of safety. Others demonstrated excellent detailing in respect of safety. Entry numbers 14, 23, 24 and 43 had considered the problem of the jacket cuff very carefully and produced a most acceptable design. Very few competitors had given much thought to the problem of the jacket hem, although entry numbers 14, 23 and 59 had considered this most carefully and produced a sensible solution.

Hoods were provided on many garments, but unfortunately many designers had failed to appreciate the requirements of the construction worker in this respect. Of all the entries submitted with hoods, only one, number 32, had provided a hood which could be pulled up over a safety helmet.

Many competitors solved the problem of trouser cuffs by providing a means of clipping them up to avoid flapping.

The colour is obviously a critical item from the point of view of safety. A number of entrants provided high visibility by submitting a garment which was so garish and bright as to be largely unacceptable to the potential wearer. Nineteen entrants either ignored the problem of safety colouring or provided a yellow garment. The most acceptable use of colour as a safety precaution was on entry numbers 14, 18 and 24, which effectively contrasted brilliant coloured panels in an otherwise sombre coloured suit. Number 18 is particularly to be commended for the imaginative way in which the right contrasting colour was used in a continuous band down the sleeves to enhance the appearance of the garment.

### Ease of movement

Not all of the entries allowed sufficiently for movement and this was particularly true of the 1-piece suits, which proved unpopular with the wearers for this reason. This type of suit would need to be manufactured in materials having some elasticity before it could be considered to be fully acceptable for most tasks on a building site, although there are some trades, such as tower crane operators, for which they are quite well suited.

### Weights

Although the recommended maximum weight of the basic suit was 4 lb, nineteen of the entries weighed less than 3 lb, and six actually weighed less than 2 lb. Only five suits out of the thirty-seven entries received weighed more than 4 lb, and of these one included what was in effect two complete suits within that weight limit, with one suit for summer, and one suit for winter. The heaviest suit received weighed 6 lb 3 oz, whilst the lightest weighed 1 lb 8 oz.

### Warmth

A number of entrants completely ignored the temperature requirements in the performance specification and provided a garment which was suitable only in a very limited temperature range, by providing a thin garment suitable for protection from rain and wind only, or an insulated or quilted garment which was suitable for exceptionally cold conditions only. Those competitors who allowed for this did so mainly by providing removeable liners to the jacket or an additional garment to be worn in colder conditions. The best solutions to this problem were those provided by entry number 13, which had a removeable foam lining covered with a proofed nylon to keep it clean and dry, number 18, which had an additional jacket which had a dual function as a liner and a summer jacket, number 48, which provided a detachable lining of P. V. C.-coated knitted nylon with a foam back, and number 24, which had a fixed lining with a mesh insert between the outer skin and the lining to provide a measure of warmth in cold weather without being excessively hot in mild conditions.

**Water resistance and permeability**

The garments were tested for water resistance and permeability both on site and under laboratory conditions.

Water resistance was tested in the laboratory by applying a hydrostatic head test taken to 50 inches of water. The water vapour permeability was determined in the laboratory by assessing the rate of air-flow across the specimen under 1 cm head of water pressure drop across it. Assessments of the results were made as impermeable where less than one-half ml/sq cm/sec of air passed through the specimen, and permeable where a greater amount of air than this quantity was passed through the fabric.

Thirty-one suits were found to be water resistant, but in every case they were also found to be impermeable. There was some discrepancy between the apparent site results and laboratory results in respect of water resistance, but this resulted from the site confusion between water resistance of the fabric, condensation within the suit and leakage through the seam. Very satisfactory water resistance was provided in the laboratory and on the site by entry numbers 16, 21, 25, 26, 27, 28, 35, 47, 48, 52, 53, 54, 55, 56 and 58, all of which had welded seams. However, an acceptable standard of water resistance was provided by numbers 13, 14, 15, 18, 23, 24, 32, 38, 41, 43, 59 and 60, all of which had stitched seams which gave an adequate level of protection to the wearer. Number 59 is notable in that its seams were so effectively made that they gave a value of 42-inch water head before they leaked, which is more than 5 times the value of the next most efficiently stitched seam. Numbers 13, 15 and 49 were highly commended in that they had no exposed seams across the shoulders and thus avoided the major cause of leakage. Certain suits of waterproofed nylon leaked at the knees, apparently as a result of heat developed by friction at this point which caused the waterproofing to lose adhesion and move relative to the fabric.

Water vapour permeability is a measure of comfort of the garments and although only numbers 36, 38 and 40 were permeable by the standards established, numbers 14 and 18 were made of a fabric which had a very low level of water vapour permeability but which did in effect, in conjunction with the absorbent fabric of the material, tend to obviate much of the condensation problem. Other designers accepted the impermeability of their material but provided a great deal of ventilation in the garment by way of overlapping panels and mesh fabrics. This was particularly well done in garments 12, 13, 15, 17, 23, 35, 48, 49, 52, 56, 58 and 59.

A unique and exceptionally well-considered design in respect of ventilation was in suits number 28 and 55 where the designer had produced bib-fronted trousers which fastened to a cutaway short sleeved jacket, designed to provide adequate through ventilation.

Water resistance and water vapour permeability are the two critical qualities in producing a suit which is both weather protective and comfortable, but it is apparent from the results of the testing that a fabric which provides both these qualities has not yet been developed for industrial clothing. Both the site and laboratory testing showed that it is possible to have either complete water resistance or a high level of permeability but not both. A high level of permeability automatically results in a low level of water resistance and vice versa. **It follows that those fabrics which rate high in terms of their water-proof qualities must rate low in terms of comfort factor.**

The garments which were most acceptable to wearers in terms of relative water-proofness and comfort were numbers 13, 14, 15, 18, 23 and 49.

## Flame resistance

It will be appreciated that safety considerations dictate that garments used in construction work should be reasonably flame-resistant although not necessarily fireproof. All materials were submitted to flammability tests based on the British Standard 3119 method of test, but omitting the washing pre-treatment.

Although twelve samples burned completely only five samples burned for an excessive period. All but five materials were satisfactory from a flammability point of view.

## Durability

**Abrasion resistance.** Considerable attention was paid both to the laboratory and site results in respect of abrasion resistance, which was related to the efficiency and the life of the garment on a construction site. In the laboratory, initial tests using the B. S. 3424 method gave very low results in a comparatively narrow range, and in order to obtain a reasonable spread of results on the fabrics submitted, experiments with various abradents were carried out. The test was finally a modified version of the B. S. 3424 test using the Martindale machine with a total applied load to 28 oz and a 180A wet-and-dry emery paper, but differing from the standard test by using the abradent in the specimen holder and the test samples on the base.

The outstanding materials in this respect were entries 12, 17, 52, 54, 56 and 58, all of which gave a very high resistance to abrasion. It was noticed that one or two materials which gave a very high level laboratory resistance to abrasion in the region of 19,000 rubs of the test described, gave a poor abrasion resistance on site. This appeared to arise from the effect of solvents, which in those cases caused the material to harden. A few materials which gave indifferent laboratory results, in respect of abrasion, were in practice apparently satisfactory. This may have been due to the rather elastic nature of the fabric.

It was also noted that under site conditions certain materials, mainly polyurethane-coated nylon and cotton drill, developed hard creases which degenerated into cracks. Those cracks chafed badly at the inside of the knees, the elbows and similar points, although the fabric showed a fair resistance to abrasion in the laboratory.

**Tensile and tongue-tear strength.** This was tested in the laboratory by a constant rate of traverse of 4 ± ½ inch/minute on samples 2 inches wide, 8 inches between jaws for tensile strength, and by a constant rate of traverse of 4 ± ½ inch/minute on samples 7 inches x 2 inches for tongue-tear strength. Careful note was made of any damage or destruction of this nature on the site-tested garments.

The highest laboratory results for tensile strength of the samples submitted was 420 lb/ft of entry number 41, whilst the lowest figure recorded was 48 lb/ft.

The results of the tongue-tear test gave a maximum value of 46 lb/ft on entry number 56, and a minimum value of 6 lb/ft which was registered by six entries. The values for the tongue-tear strength averaged 12 lb/ft, and the range was not so wide as for other tests.

**Effect of solvents.** The solvents chosen were those considered most likely to be used on construction sites, i.e. petrol, diesel oil, mineral oil, paraffin and white spirit. For the first test separate samples of each fabric were immersed in each solvent for 48 hours to obtain some indication of the possible effect of prolonged contact. As this produced serious deterioration of many P. V. C. -type fabrics, a second test was carried out reducing the time of immersion to four hours.

Staining of any garments on site was also investigated to determine the cause as a complement to the laboratory test.

Entry numbers 13, 14, 15, 18, 23, 24, 31, 32, 35, 36, 39, 40, 41, 43, 44, 49, 57, 59 and 61 were unaffected by solvents. Of the remainder a considerable number hardened appreciably after contact with all solvents and it was noted that in general these were the ones which had given very high values in respect of abrasion resistance. The conclusion to be drawn from this is that those materials which hardened appreciably in contact with solvents will deteriorate rapidly on most construction sites where one or other of these solvents will be encountered at some time during the effective life of the garment.

**Colour fastness.** Although not critical in respect of the efficiency of weather-protective clothing, an excessive fading or colour change could be objectionable from many points of view and particularly when colour bleeding occurs under certain conditions. For this reason tests were carried out as follows: for fastness to light, in accordance with B. S. 1006 using Xenotest exposure with controlled temperature and humidity; for weathering, using Xenotest exposure and with high humidity; for washing, as for I. S. O. wash tests but using detergents; for perspiration, as in S. D. C. report, third edition; and for rubbing, in accordance with B. S. 2677.

Virtually all the outer garments were found to be quite satisfactory in respect of colour fastness. However, the same could not be said for quilted linings and additional inner garments, a large number of which were found to stain badly with perspiration and to lose colour from rubbing - some notable exceptions to this being entries number 48, 44, 57 and 59.

**Bond strength.** Five of the suits had a lining bonded to the outer fabric and tests were carried out on these to determine the bond strength between the two materials. The test measured the load in grams to delaminate a 1-inch width sample of the fabric when in a wet condition. Two suits gave values as low as 40 and 50 grams, which indicated that in prolonged use they would probably delaminate, but only one showed any signs of delamination under site conditions.

**Heat ageing.** In this test the sample sizes were modified from the standard size of 5 inches by 1½ inches to 4. 2 inches by 2 inches for subsequent flex cracking tests. Only four of the thirty-seven samples tested were affected, and the cockling of the samples in these cases was probably caused by the shrinkage of the P. V. C. coating.

**Shrinkage.** This test was carried out by immersing the sample for two hours in cold water. Most of the fabrics submitted to this test showed a shrinkage of less than 1 per cent. Four entries suffered significant shrinkage to an extent which might affect the efficiency of the garment. One fabric had a shrinkage rate of 4. 8 per cent or almost 1½ inches in the length of the trouser leg.

It was noted that generally P. V. C. -based materials were more resistant to shrinkage than the other materials in the competition, although this was not invariably true.

**Resistance to cracking.** The laboratory tests of the samples were carried out to determine resistance to flex cracking and the cold crack temperature. In the case of the former, the Schildnecht test on heat age samples was run to 250,000 cycles. The cold crack temperature was determined as the temperature at which 50 per cent of the test specimens cracked when folded flat under defined and reproduceable conditions. All the materials withstood the Schildnecht test, although five fabrics failed to withstand the cold crack test - failing at temperatures of minus 17.5°C, minus 18.5°C, two at minus 19.5°C, and one at minus 21.5°C. As those temperatures were very low, it was considered that for practical purposes all the entries were satisfactory in this respect.

The site experience showed that the coating on three suits of polyurethane-coated nylon tended to crack. This did not detract from the strength of the garment but allowed water to leak into it at these points. Surprisingly some site trouble was also experienced with polyurethane-proofed cotton drill which produced similar problems.

## Manufacture

There was a great variation in the quality of manufacture and many entrants disregarded the requirements of the outline performance specification under this heading. It was apparent from an examination of the laboratory and site results that some manufacturers of protective clothing have very little control over quality of the various fabrication and assembly operations.

## Fastenings

Although there was a specific requirement in the outline performance specification for fastenings to be able to withstand a loading of 100 lb, only entry numbers 43 and 48 achieved this figure in the course of testing. The zip fastenings were in general stronger than button fastenings, which in turn were stronger than press-studs. It was apparent from on-site testing and laboratory testing that press-studs used alone for the main fastening for the front of the garments are seldom strong enough. Button fastenings varied in strength and in some cases were a lot stronger than many of the zip fastenings, the most notable in this respect being suits number 53, which achieved a strength across the line of the buttons of 60 lb/ft, at which loading the button hole tore, and number 59, a loading of 68 lb/ft when the button thread broke. The only outstanding garment using a press-stud fastening was entry number 15, which achieved 60 lb/ft across the line of the press-studs; this was four times the loading achieved by the next strongest press-stud fastening. Of the fifteen garments which used zip fastenings seven gave trouble or failed under site conditions. Of the twelve entries using button fastenings down the front, five lost one or more buttons. In one case the garment lost all its buttons after being worn on site for less than one month. Of the five garments with press-stud fastenings down the front many gave trouble as a direct result of being jammed by particles of cement or concrete dust, and being torn out of the base fabric - the one exception to this being all the garments submitted under entry number 15.

## Seams

Seam strengths revealed a great discrepancy between the garments. However, entry numbers 43 and 58 provided the highest seam strengths of all and in conjunction with a very strong material must be considered to be the two best suits from the point of view of their strength. Many of the seam strengths were alarmingly low, particularly in such critical locations as the sleeve to body seam and the centre back seam of the trousers. Three garments had a great variation in the sleeve-to-body seam strength on the one sample tested. Many of the suits made of material with a very high tensile strength had a relatively low seam strength which could easily be remedied in most instances by the use of a stronger sewing thread.

## Pockets

The design of external pockets on many garments showed originality and a careful consideration of the problems of weather protection and safety. It was pleasing to note that many garments with orthodox types of pockets covered by a flap had provided Velcro or press-stud fastening to hold the flap down over the pocket. The most outstanding garments in respect of pocket design were numbers 13, 24, 48, 49 and 59 and the general arrangement of pockets was outstanding in garment number 18.

## Size

The size of the sample garments submitted was required to be B. S. size 40. The sizing of the garments was more varied than the quality of assembly, even allowing for variation in design. Not one suit was made to the exact dimensions of B. S. 40, but entry numbers 18 and 40 were closest in measured dimensions.

However, actual dimensions notwithstanding, entry numbers 13, 14, 15, 18, 24, 36, 48, 49, 51 and 59 provided a suit which, having due regard to the design, fitted an average size 40 man well, and as this is the basic intention of manufacturing to a given size, these are commended for that.

## PART VI

## The Results

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The Assessment Panel considered the results of the laboratory and site testing in detail against the requirements set out in the competition conditions. Analysis of the entries complying with the requirements enabled certain entries to be selected for closer consideration.

An exhaustive examination of the merits and defects of these selected garments showed that one, although not perfect in design or manufacture, came closest to meeting the requirements detailed in the competition conditions. This was a 2-piece suit of polyurethane-coated nylon with a removeable liner of foam-backed nylon. Site experience showed that this entry was highly acceptable in appearance to the average wearer and with the combination of different accessories it was suitable for most weather conditions encountered in Britain. The garments were reasonably designed to take account of safety on construction sites and the arrangement of pockets was satisfactory. The fitting of the garments was such that they did not restrict movement when carrying out the various tasks on construction sites.

The physical characteristics of this entry complied with most of the requirements in the competition conditions. The trial weight of the complete suit was 2 lb 3¾ oz. Warmth could be achieved by adding or removing the foam-backed lining. The water resistance was high on the fabric and adequate for the seams. Ventilation was provided across the shoulders and front of the jacket by using a cape type shoulder with ventilation under the edges of the cape. The flame resistance was adequate for construction purposes.

The material for the outer garments provided a reasonable standard of resistance to abrasion, giving a resistance of 4,300 rubs on the modified Martindale test before it wore into holes. The tear strength was well in excess of the minimum required, being 24 lb foot in the length and 22 lb foot in the width, with a tensile strength of 240 lb foot and 329 lb foot respectively. The colour fastness was entirely satisfactory as no changes in shade were recorded and only slight staining was noted. No samples of this fabric were affected by solvents, and the resistance to cracking was entirely adequate.

The manufacture of this entry was satisfactory and although the strength of fastenings did not reach the levels required in the performance specification they were adequate, particularly bearing in mind that only one garment submitted did meet the standard laid down. The front fastening of the jacket was a nylon zip with a flyover cover secured by press-studs. In addition there was a draw-string in the waist of the jacket which could be used to provide additional fastening. The trousers were supported by an elasticated waist. The seams were of adequate strength and water resistance, although it was felt that stronger sewing thread might have been used to match the quality of the fabric. Two external pockets were provided, each of which was a slanted inset pocket with a press-stud fastening.

The price of the garment was considered, in addition to its acceptability to the wearer, its relationship to the basic requirements of the competition and the quality of manufacture and fabric. The price in this instance to the bulk user was £6 19s. 6d. complete including purchase tax, which the Assessment Panel felt was not unreasonable in view of the features which the suit provided, and the quality of manufacture and materials. It was decided unanimously that entry no. 13 manufactured by Messrs. Jeltek Ltd. was the winner of the competition.

Of the other garments which the panel considered in great detail, entry no. 15, although lacking pockets and any provision for extremely cold weather in its design, appealed because of the quality of the fabric used (a polyurethane-coated nylon with a silicone finish). Moreover, this 2-piece suit had five extremely good press-stud fastenings and was lined. The price to bulk users was £4 10s. 7d. including purchase tax. Taking into account also the relevant test data it was decided to award the second prize to entry no. 15, manufactured by Messrs. Watsons (Newburgh) Ltd.

For the third prize the panel chose suit no. 59, manufactured by Messrs. Belstaff Ltd. , because of the quality of manufacture, the excellent detailing of the pockets which were quite outstanding, the strength of the button fastenings and the test data which revealed the many virtues of this suit. Entry no. 59 was a polyurethane-coated silicone-proofed nylon 2-piece suit, with additional inner warmth provided by a single-breasted quilted jerkin. Its price to bulk users was £7 0s. 2d. including purchase tax.

The Panel commends entries number 14 and 18 for their ergonomic design and successful use of colour to produce garments with exceptional acceptability to the wearer and giving a high safety rating.

It is hoped that the good points of these designs may promote more original thinking which, if allied to suitably durable materials, could produce the weather-protective clothing of the future.

The Assessment Panel and the Ministry of Public Building and Works wish to thank all the entrants for their enthusiasm and effort, which showed very clearly that the desire and the ability to produce protective clothing suitable for modern conditions does exist within the Clothing Industry. They also wish to thank their colleagues in the Construction Industry for their willing co-operation in site testing and in particular the wearers on different sites who patiently endured the frequent visits and interviews. Finally, grateful mention should be made of the advice and assistance received from the Retail Trading Standards Association's laboratory and its Technical Director.

# APPENDIX A

## List of Entrants

The following is the list of entrants in the Protective Clothing Competition:

| | Entry Number |
|---|---|
| Ammondon Safety Products Ltd., 522 Kingston Road, Raynes Park, London, S.W. 20 | 44 57 |
| George Angus & Co. Ltd., Angus Fire Armour Division, Angus House, 150/158 Westgate Road, Newcastle upon Tyne, 1 | 17 56 |
| Belstaff Manufacturing Co. Ltd., Caroline Street, Longton, Stoke-on-Trent | 21 59 60 |
| A. D. Crompton (Industrial) Ltd., Sovereign Street, Salford, 6 | 52 |
| Ellis Overalls (Halifax) Ltd., Unity Works, Gaol Lane, Halifax | 38 |
| Howard Flint Ltd., Pell Lane, Ryde, Isle of Wight | 24 |
| Harvingdale Manufacturing Co. Ltd., Milestone Works, 238-248 London Road, Romford, Essex | 16 |
| Husky of Tostock Ltd., Woolpit, Suffolk | 31 43 |
| Ideal Weatherproofs Ltd., Bishop Street, Cork | 47 54 |
| Jeltek Ltd., Jel House, Staines Road, Hounslow, Middlesex | 13 48 49 |
| Kagan Textiles Ltd., Gannex Mills, Elland, Yorkshire | 32 |
| Lybro of Liverpool Ltd., Lybro Works, Mount Vernon, Liverpool, 7 | 18 |
| Multifabs Ltd., Osmaston Works, Derby | 14 |

|  | Entry Number |
|---|---|
| James North & Sons Ltd., P. O. Box No. 3, Hyde, Cheshire | 25 26 27 |
| Pakamac Special Products Ltd., Melbourne Mill, Chadderton, Lancs | 23 53 |
| Personnel Protection Ltd., Avalon Works, 105 High Street, Rickmansworth, Herts. | 39 |
| Pynford Ltd., 74 Lancaster Road, Stroud Green, London, N. 4 | 28 55 |
| R. F. D. Co. Ltd., Godalming, Surrey | 40 41 |
| Scaffolding (Great Britain) Ltd., Mitcham, Surrey | 35 |
| Robert Watson & Co. Ltd., 12 Theobalds Road, London, W. C. 1 | 12 58 |
| Watsons (Newburgh) Ltd., Newburgh, Fife | 15 |
| Wood Harris & Co. Ltd., Halifax | 36 |

## APPENDIX B

## Laboratory and sites

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**Laboratory Testing was done by:**
The Retail Trading Standards Association

**Site Testing was done by:**
Gilbert Ash Ltd.
M. & F. O. Foster and Sons Ltd.
John Laing Research and Development Ltd.
Nottingham County Architects Department
Scottish Special Housing Association Ltd.
County Borough of Sunderland Public Works Department
Taylor Woodrow Construction Ltd.
George Wimpey and Co. Ltd.

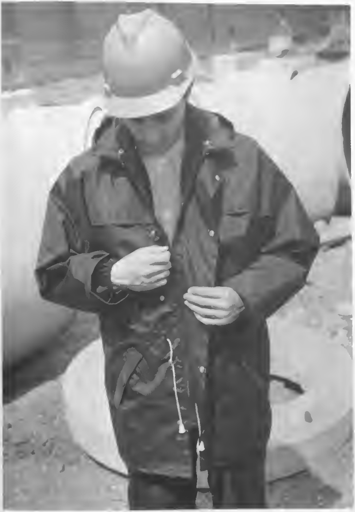

Fig. 1

The winning entry no. 13

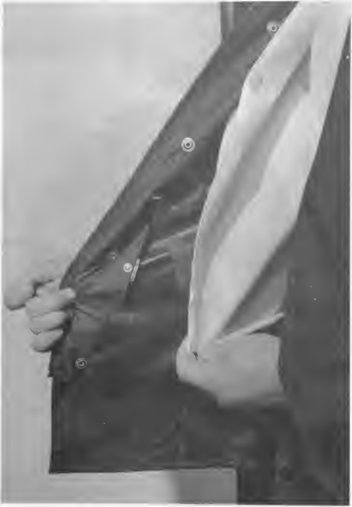

Fig. 2

Lining to entry no. 13, showing arrangement of press studs for fastening

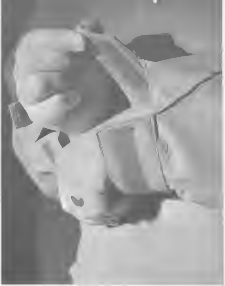

Fig. 3

Detail of cuff on entry no. 14, showing variable adjustment for closing sleeve

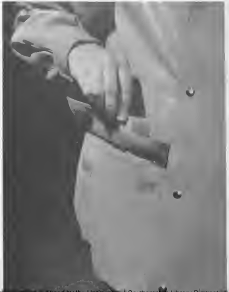

Fig. 4

Arrangement for fastening flap on pocket of entry no. 14

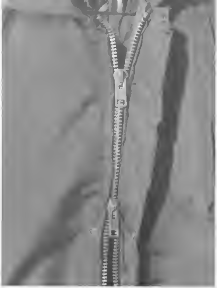

Fig. 5

Heavy zip with two-way fastening on entry no. 31

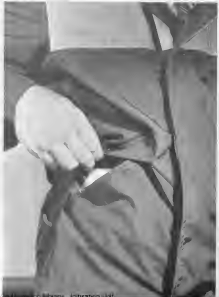

Fig. 6

Waterproof pocket design on entry no. 24

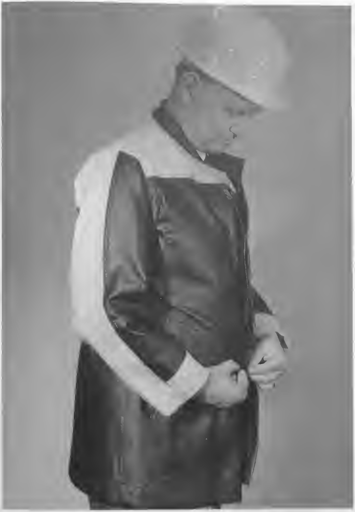

Fig. 7

Colour treatment on entry no. 18, showing contrasting colour carried across back and down sleeves

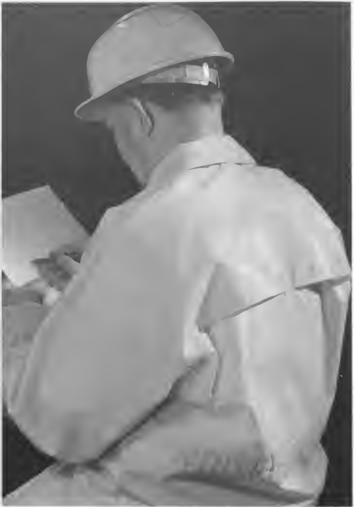

Fig. 8

Entry no. 49 showing back panel with no exposed seams across the shoulders

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